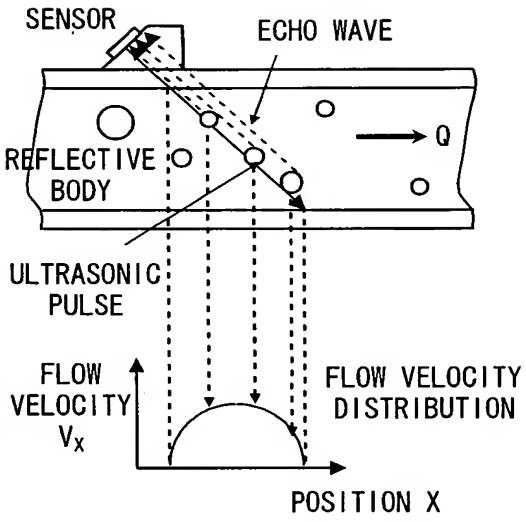
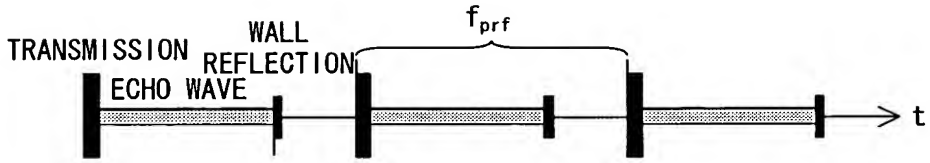


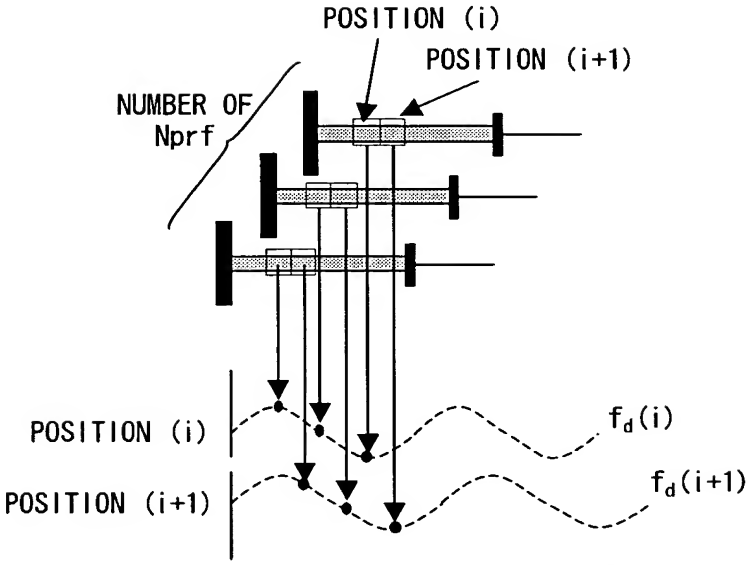

CONFIGURATION OF PULSE DOPPLER METHOD

FIG. 1A



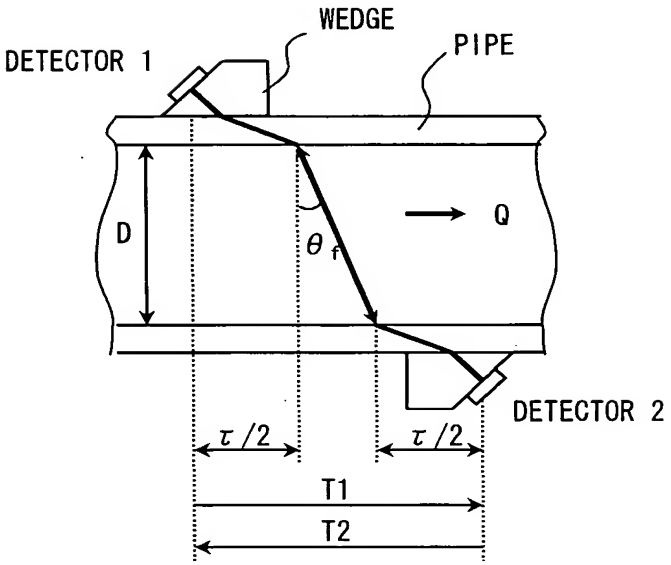

TIME TRANSITION OF RECEIVED WAVE

FIG. 1B



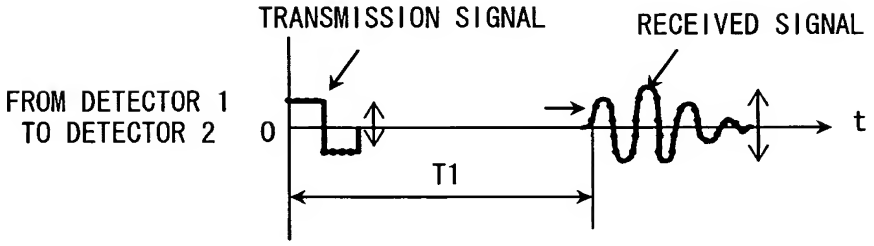

CONCEPTUAL DIAGRAM OF MEASUREMENT

FIG. 1C



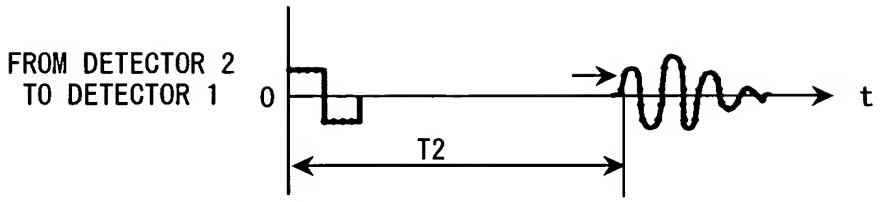

CONFIGURATION OF TRANSIT TIME METHOD

FIG. 2A




FROM DETECTOR 1 TO DETECTOR 2

FIG. 2B




FROM DETECTOR 2 TO DETECTOR 1

FIG. 2C

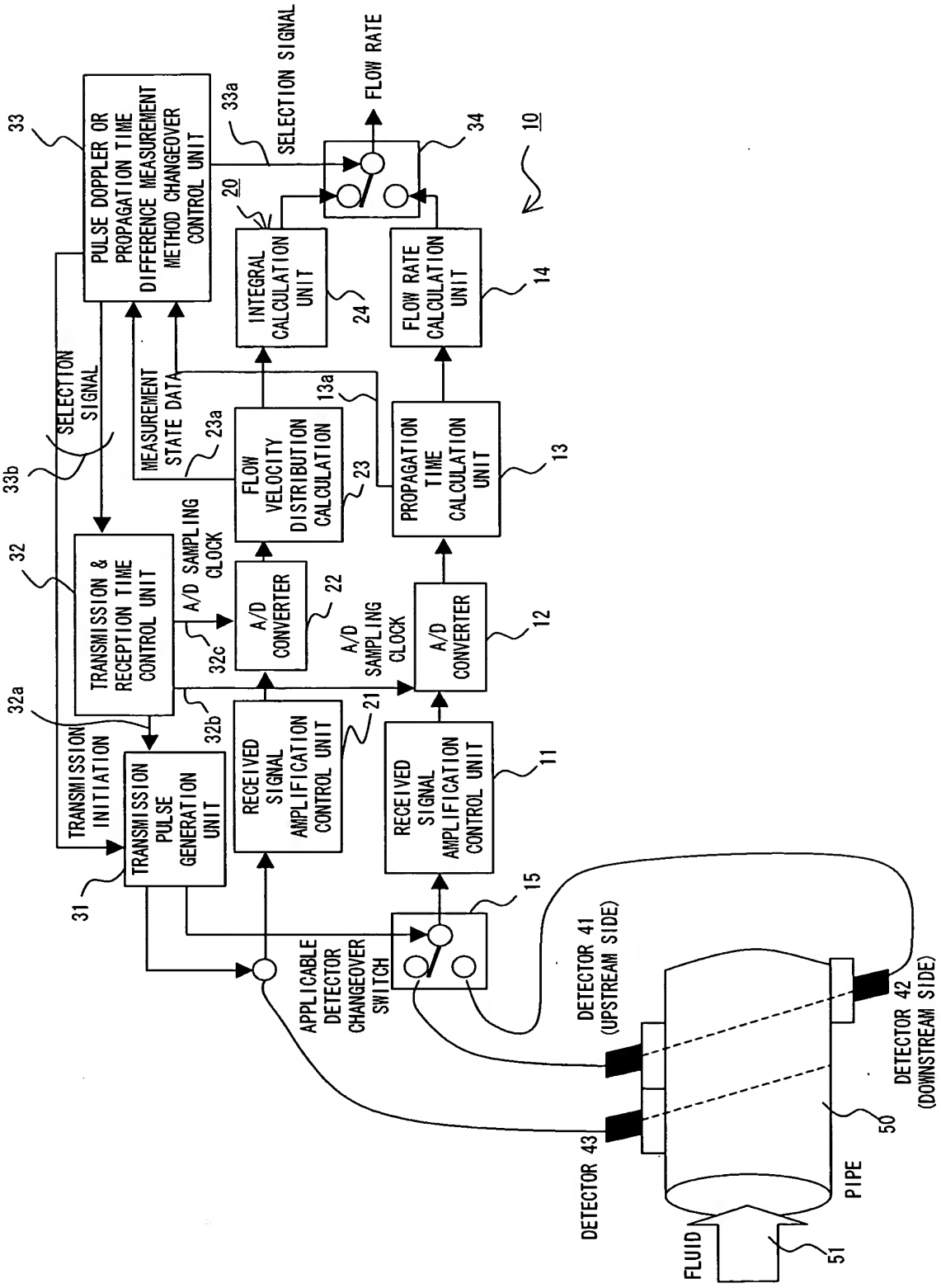

PULSE DOPPLER OR PROPAGATION TIME DIFFERENCE MEASUREMENT METHOD CHANGEOVER CONTROL UNIT
SELECTION SIGNAL
FLOW RATE
INTEGRAL CALCULATION UNIT
FLOW RATE CALCULATION UNIT
MEASUREMENT STATE DATA
FLOW VELOCITY DISTRIBUTION CALCULATION
PROPAGATION TIME CALCULATION UNIT
TRANSMISSION & RECEPTION TIME CONTROL UNIT
A/D SAMPLING CLOCK
A/D CONVERTER
A/D CONVERTER
TRANSMISSION INITIATION
TRANSMISSION PULSE GENERATION UNIT
RECEIVED SIGNAL AMPLIFICATION CONTROL UNIT
RECEIVED SIGNAL AMPLIFICATION CONTROL UNIT
APPLICABLE DETECTOR CHANGEOVER SWITCH
DETECTOR 41 (UPSTREAM SIDE)
DETECTOR 42 (DOWNSTREAM SIDE)
DETECTOR 43
PIPE
FLUID
10
11
12
13
14
15
20
21
22
23
24
31
32
32a
32b
32c
33
33a
33b
34
50
51
13a
23a

FIG. 3

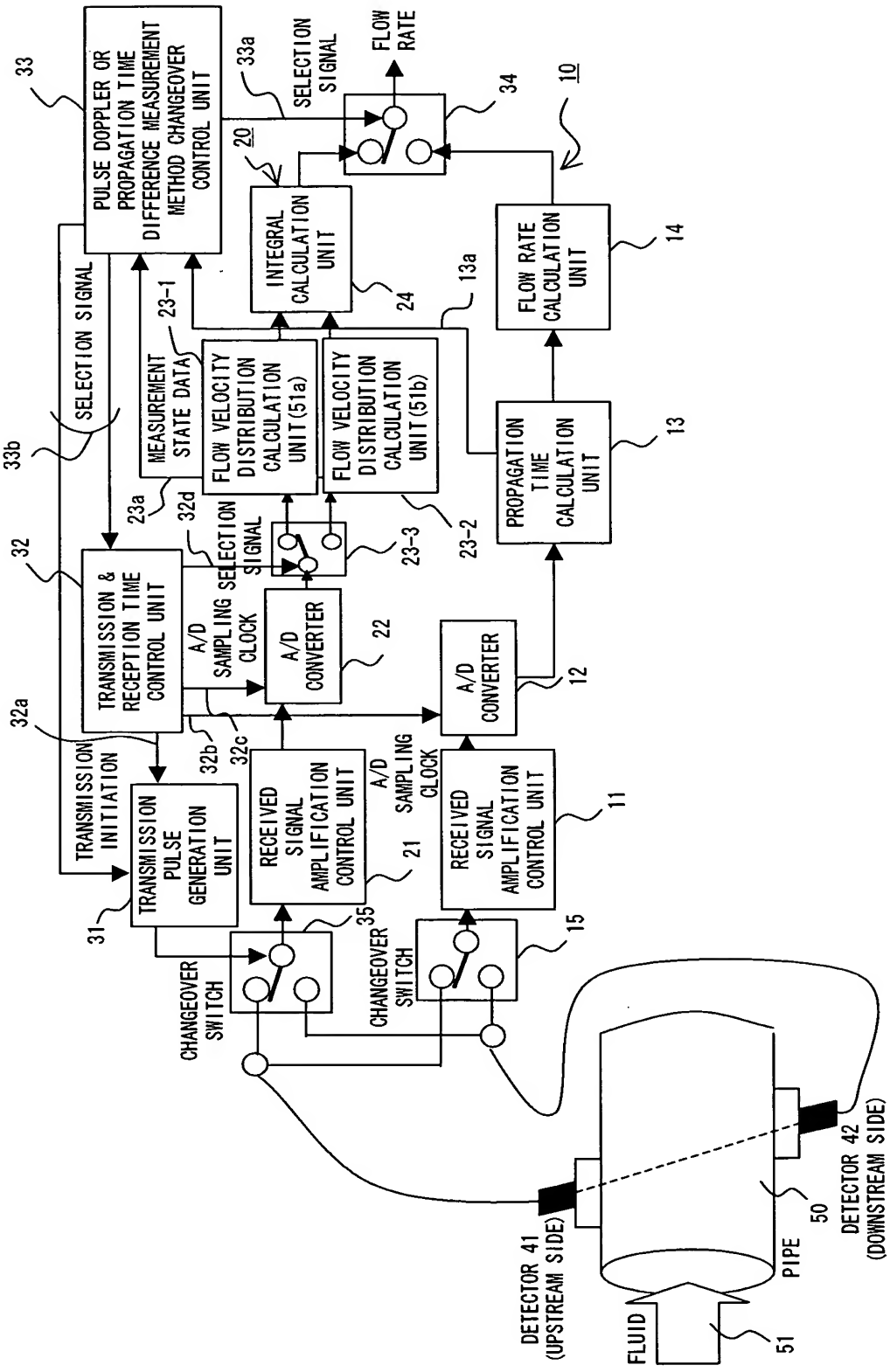

PULSE DOPPLER OR PROPAGATION TIME DIFFERENCE MEASUREMENT METHOD CHANGEOVER CONTROL UNIT
33
SELECTION SIGNAL
33a
FLOW RATE
34
10
20
INTEGRAL CALCULATION UNIT
24
FLOW RATE CALCULATION UNIT
14
13a
SELECTION SIGNAL
33b
MEASUREMENT STATE DATA
23-1
FLOW VELOCITY DISTRIBUTION CALCULATION UNIT(51a)
FLOW VELOCITY DISTRIBUTION CALCULATION UNIT(51b)
PROPAGATION TIME CALCULATION UNIT
13
23a
32d
SELECTION SIGNAL
23-3
23-2
32
TRANSMISSION & RECEPTION TIME CONTROL UNIT
A/D SAMPLING CLOCK
A/D CONVERTER
22
A/D CONVERTER
12
32a
TRANSMISSION INITIATION
32b
32c
RECEIVED SIGNAL AMPLIFICATION CONTROL UNIT
21
A/D SAMPLING CLOCK
RECEIVED SIGNAL AMPLIFICATION CONTROL UNIT
11
TRANSMISSION PULSE GENERATION UNIT
31
35
CHANGEOVER SWITCH
CHANGEOVER SWITCH
15
DETECTOR 41 (UPSTREAM SIDE)
DETECTOR 42 (DOWNSTREAM SIDE)
50
PIPE
FLUID
51

FIG. 4

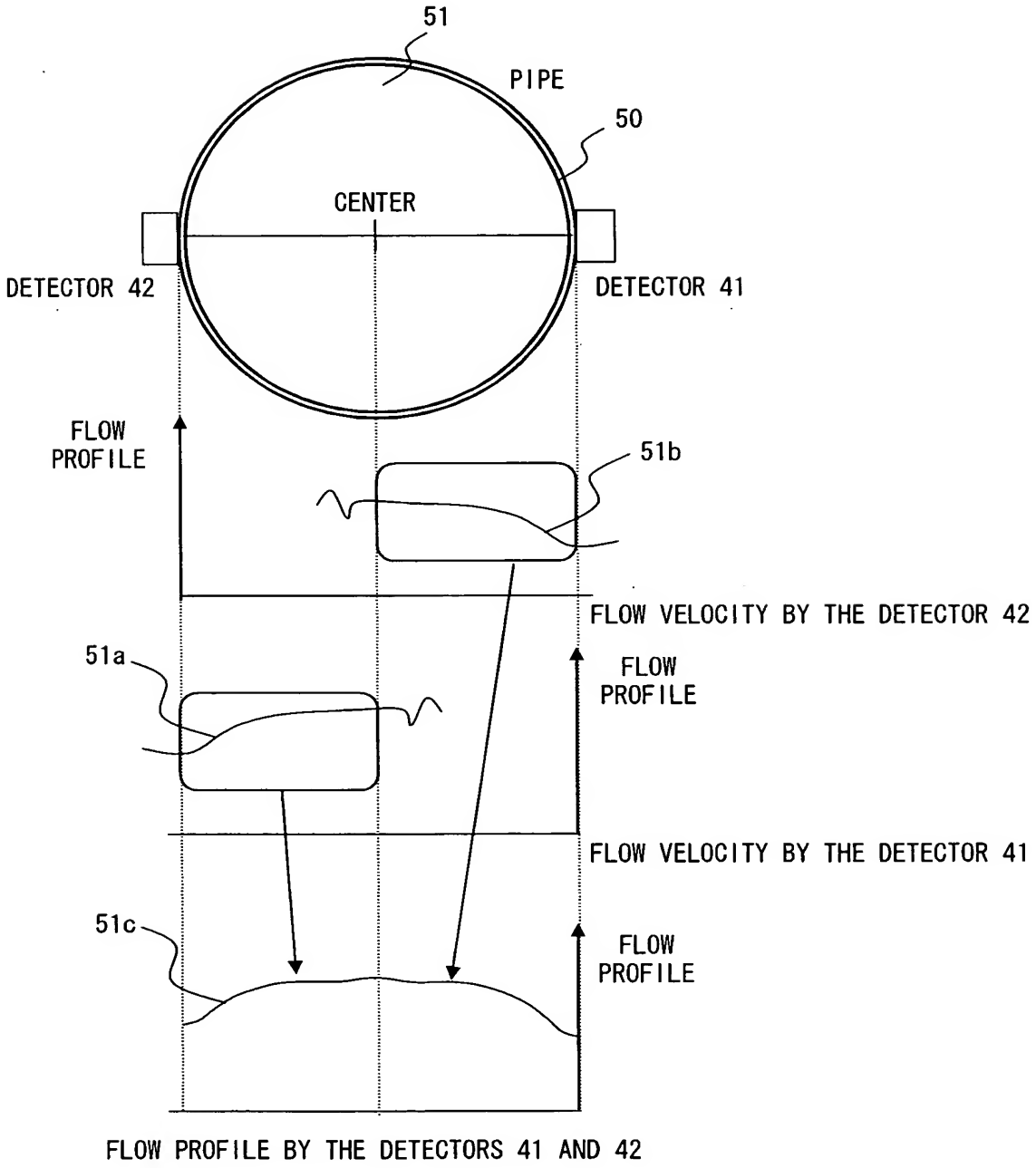

51
PIPE
50
CENTER
DETECTOR 42
DETECTOR 41
FLOW PROFILE
51b
FLOW VELOCITY BY THE DETECTOR 42
51a
FLOW PROFILE
FLOW VELOCITY BY THE DETECTOR 41
51c
FLOW PROFILE
FLOW PROFILE BY THE DETECTORS 41 AND 42

FIG. 5

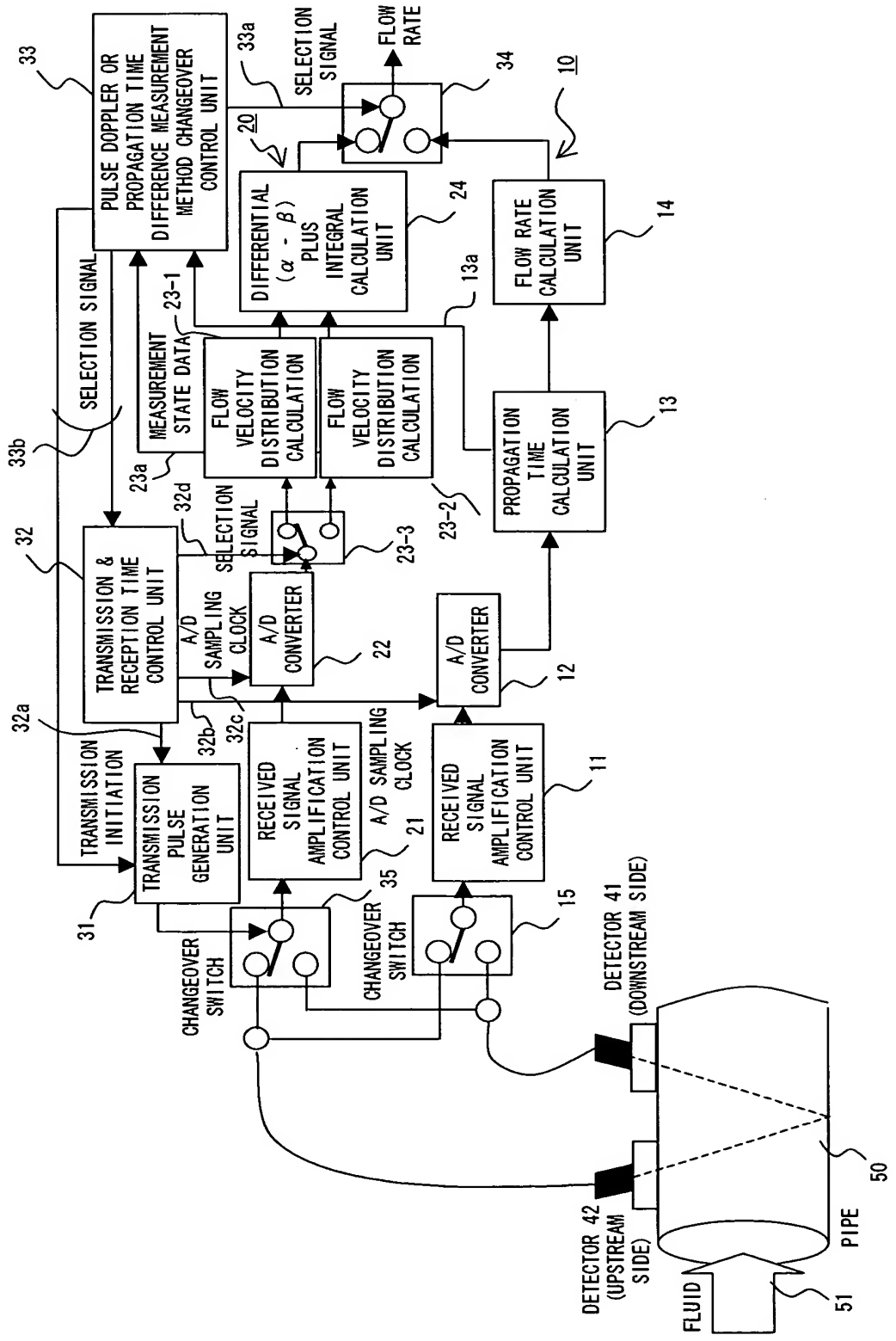

PULSE DOPPLER OR PROPAGATION TIME DIFFERENCE MEASUREMENT METHOD CHANGEOVER CONTROL UNIT
33
33a
SELECTION SIGNAL
FLOW RATE
34
10
20
DIFFERENTIAL (α - β) PLUS INTEGRAL CALCULATION UNIT
24
FLOW RATE CALCULATION UNIT
14
13a
SELECTION SIGNAL
23-1
MEASUREMENT STATE DATA
FLOW VELOCITY DISTRIBUTION CALCULATION
FLOW VELOCITY DISTRIBUTION CALCULATION
PROPAGATION TIME CALCULATION UNIT
13
33b
23a
32d
SELECTION SIGNAL
23-3
23-2
32
TRANSMISSION & REGEPTION TIME CONTROL UNIT
A/D SAMPLING CLOCK
A/D CONVERTER
22
A/D CONVERTER
12
32a
32b
32c
TRANSMISSION INITIATION
TRANSMISSION PULSE GENERATION UNIT
RECEIVED SIGNAL AMPLIFICATION CONTROL UNIT
A/D SAMPLING CLOCK
21
RECEIVED SIGNAL AMPLIFICATION CONTROL UNIT
11
31
35
15
CHANGEOVER SWITCH
CHANGEOVER SWITCH
DETECTOR 41 (DOWNSTREAM SIDE)
DETECTOR 42 (UPSTREAM SIDE)
50
PIPE
FLUID
51

FIG. 6

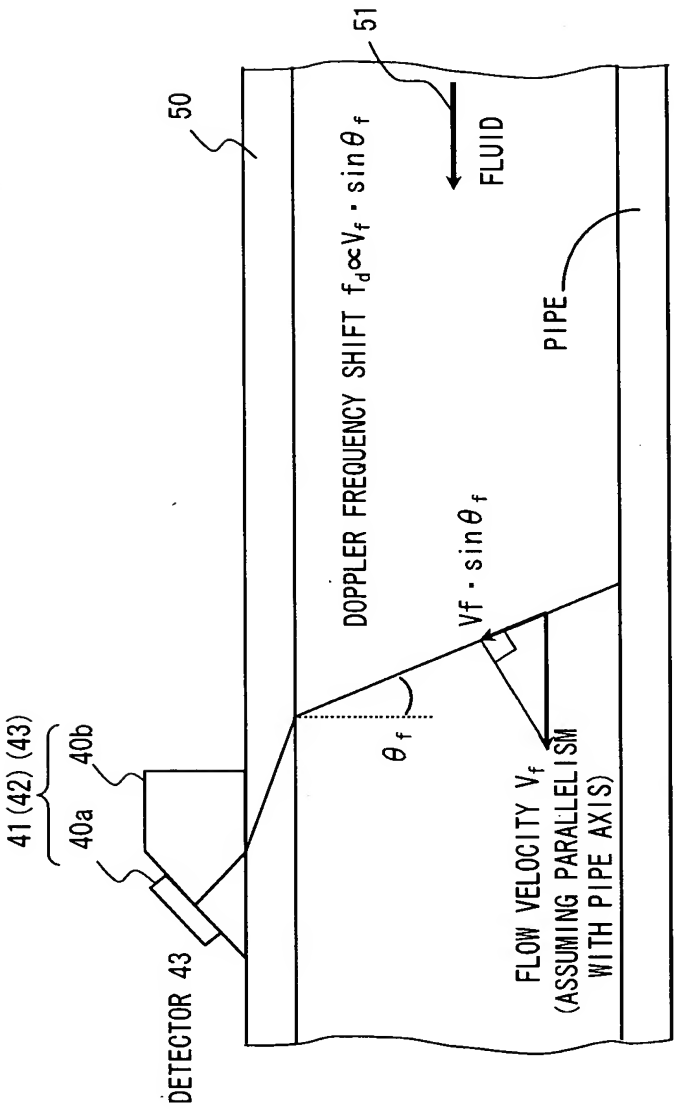

51
50
FLUID
DOPPLER FREQUENCY SHIFT $f_d \propto V_f \cdot \sin\theta_f$
PIPE
$Vf \cdot \sin\theta_f$
41 (42) (43)
40b
40a
$\theta_f$
FLOW VELOCITY $V_f$
(ASSUMING PARALLELISM WITH PIPE AXIS)
DETECTOR 43

FIG. 7

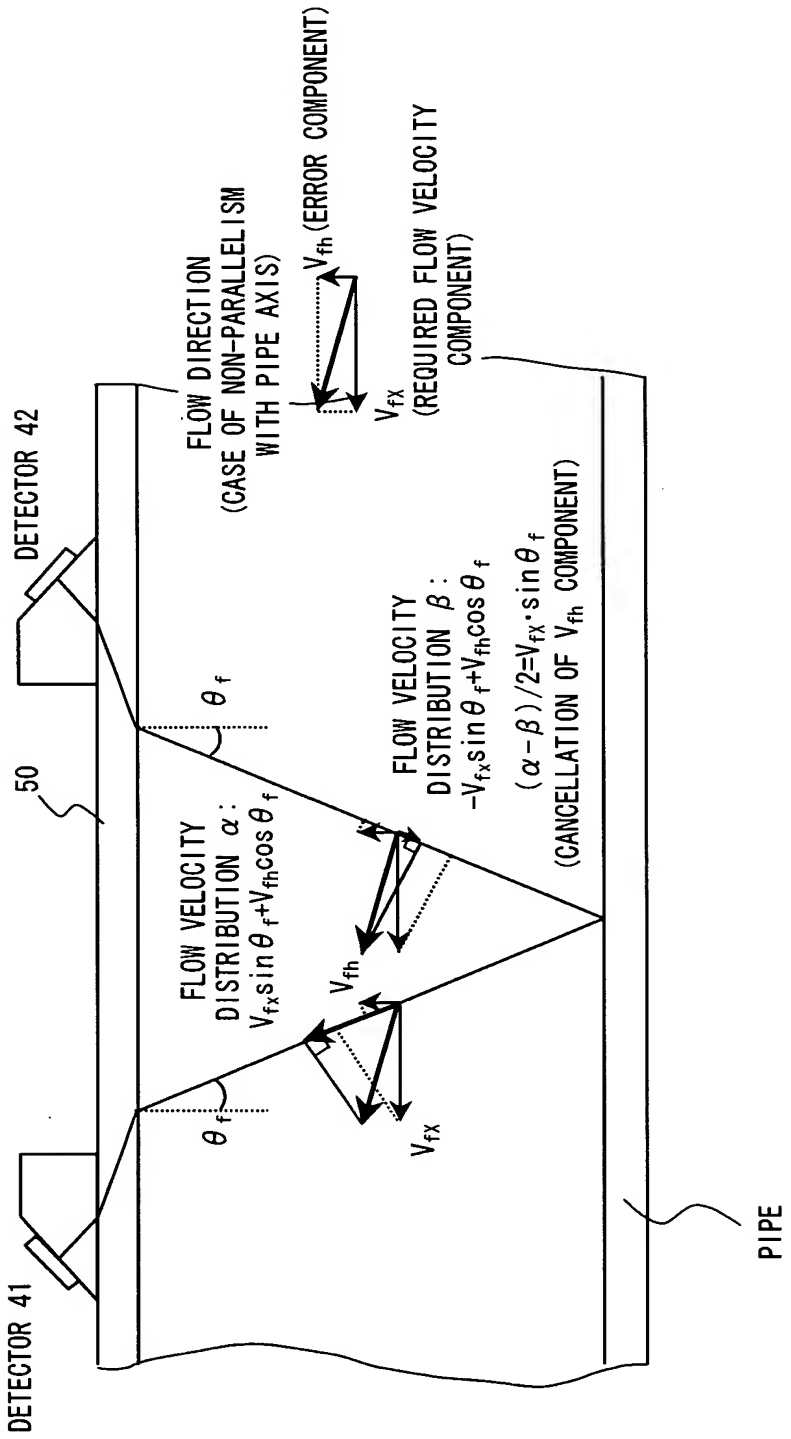

FLOW DIRECTION
(CASE OF NON-PARALLELISM
WITH PIPE AXIS)
$V_{fh}$ (ERROR COMPONENT)
$V_{fX}$
(REQUIRED FLOW VELOCITY
COMPONENT)
DETECTOR 42
$\theta_f$
50
FLOW VELOCITY
DISTRIBUTION $\alpha$:
$V_{fX}\sin\theta_f+V_{fh}\cos\theta_f$
FLOW VELOCITY
DISTRIBUTION $\beta$:
$-V_{fX}\sin\theta_f+V_{fh}\cos\theta_f$
$(\alpha-\beta)/2=V_{fX}\cdot\sin\theta_f$
(CANCELLATION OF $V_{fh}$ COMPONENT)
$V_{fh}$
$\theta_f$
$V_{fX}$
DETECTOR 41
PIPE

FIG. 8

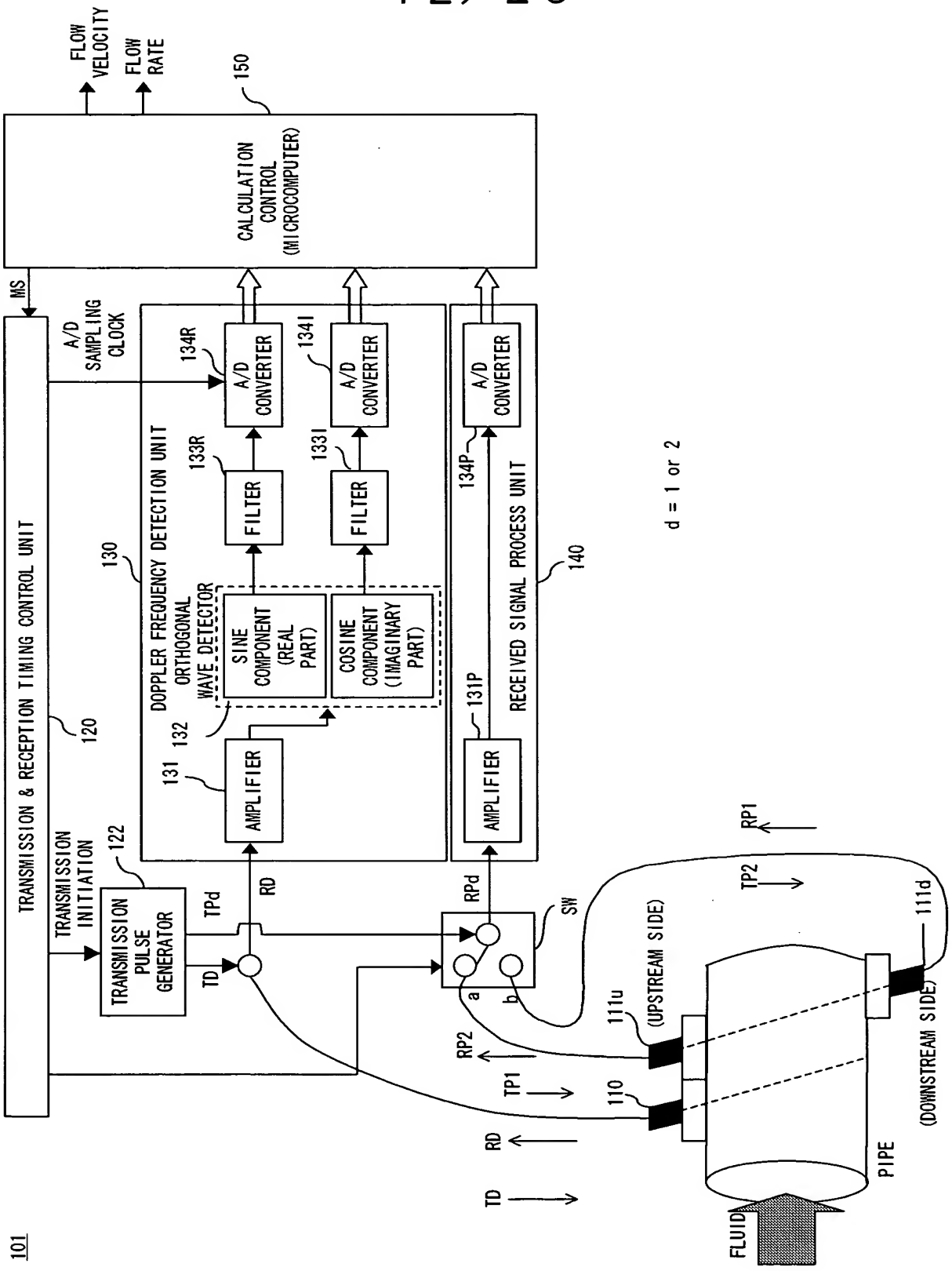

FLOW VELOCITY
FLOW RATE
150
CALCULATION CONTROL (MICROCOMPUTER)
MS
A/D SAMPLING CLOCK
TRANSMISSION & RECEPTION TIMING CONTROL UNIT
120
TRANSMISSION INITIATION
122
TRANSMISSION PULSE GENERATOR
TPd
TD
RD
DOPPLER FREQUENCY DETECTION UNIT
130
ORTHOGONAL WAVE DETECTOR
132
SINE COMPONENT (REAL PART)
COSINE COMPONENT (IMAGINARY PART)
131
AMPLIFIER
133R
1331
FILTER
134R
1341
A/D CONVERTER
RECEIVED SIGNAL PROCESS UNIT
140
131P
134P
RPd
SW
a
b
d = 1 or 2
RP1
TP2
RP2
TP1
RD
TD
111u
(UPSTREAM SIDE)
111d
(DOWNSTREAM SIDE)
110
PIPE
FLUID
101

FIG. 9

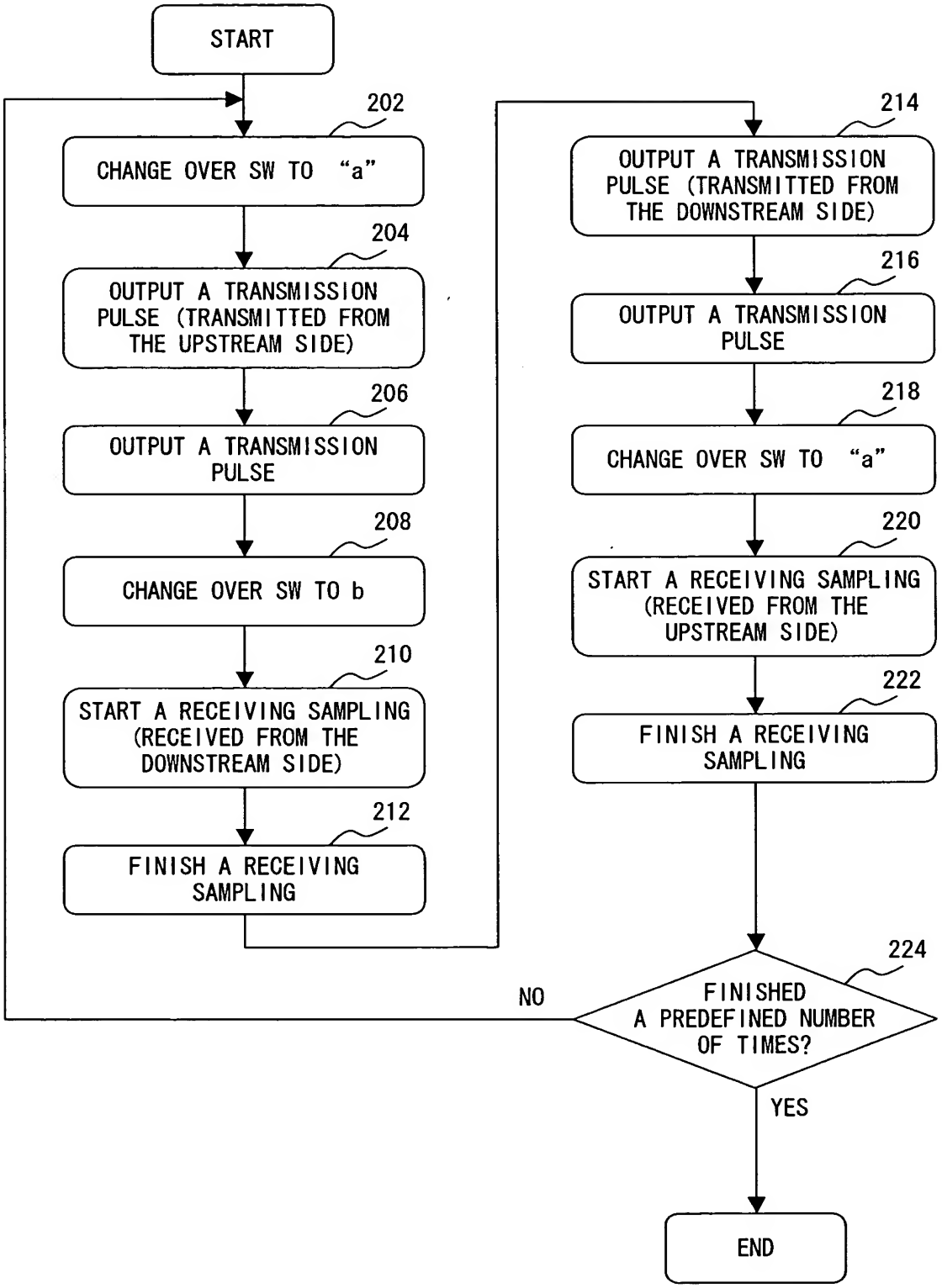

START
202
CHANGE OVER SW TO "a"
204
OUTPUT A TRANSMISSION PULSE (TRANSMITTED FROM THE UPSTREAM SIDE)
206
OUTPUT A TRANSMISSION PULSE
208
CHANGE OVER SW TO b
210
START A RECEIVING SAMPLING (RECEIVED FROM THE DOWNSTREAM SIDE)
212
FINISH A RECEIVING SAMPLING
214
OUTPUT A TRANSMISSION PULSE (TRANSMITTED FROM THE DOWNSTREAM SIDE)
216
OUTPUT A TRANSMISSION PULSE
218
CHANGE OVER SW TO "a"
220
START A RECEIVING SAMPLING (RECEIVED FROM THE UPSTREAM SIDE)
222
FINISH A RECEIVING SAMPLING
224
FINISHED A PREDEFINED NUMBER OF TIMES?
NO
YES
END

FIG. 10

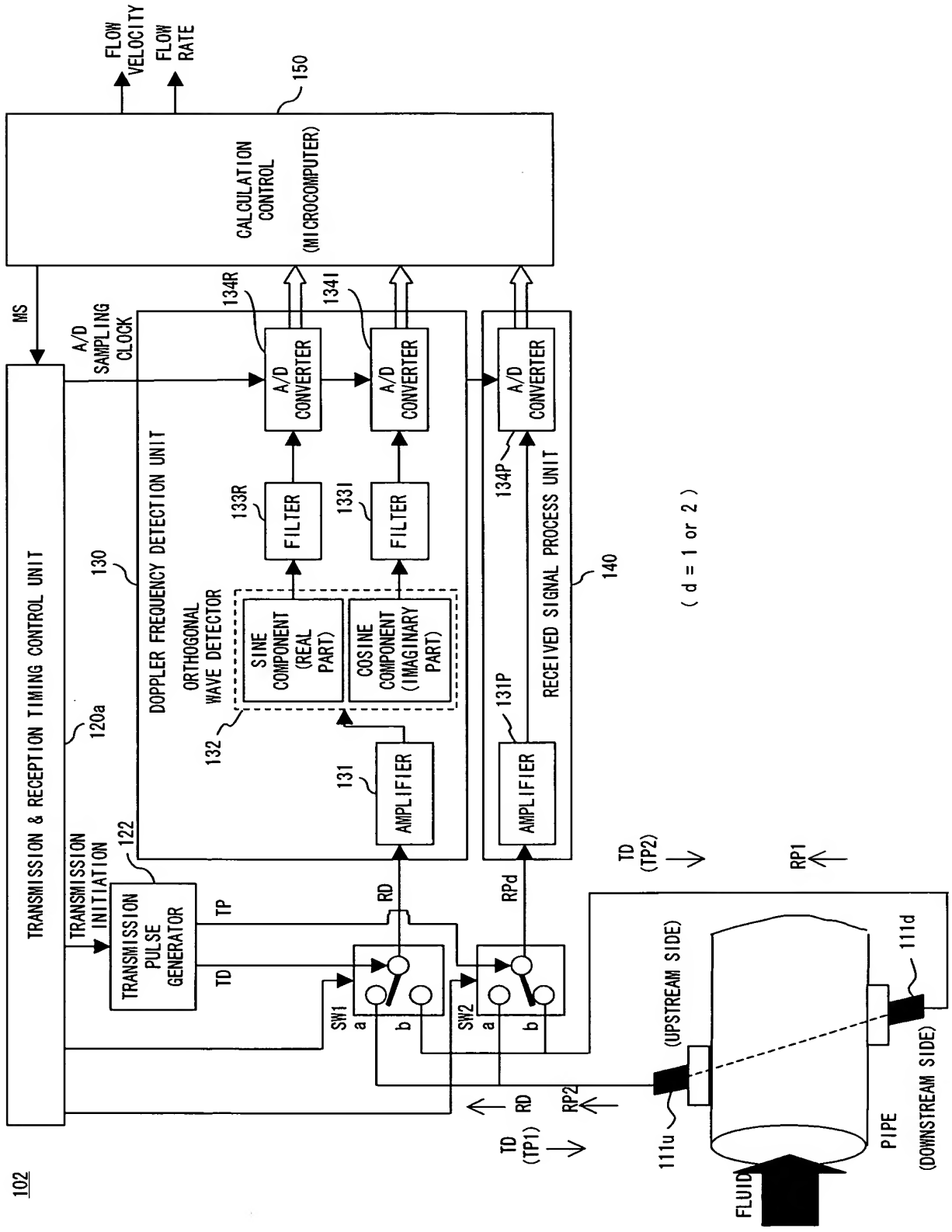

FLOW VELOCITY
FLOW RATE
150
CALCULATION CONTROL (MICROCOMPUTER)
MS
A/D SAMPLING CLOCK
134R
134I
A/D CONVERTER
A/D CONVERTER
A/D CONVERTER
133R
133I
FILTER
FILTER
134P
DOPPLER FREQUENCY DETECTION UNIT
130
ORTHOGONAL WAVE DETECTOR
SINE COMPONENT (REAL PART)
COSINE COMPONENT (IMAGINARY PART)
132
131
AMPLIFIER
131P
AMPLIFIER
RECEIVED SIGNAL PROCESS UNIT
140
( d = 1 or 2 )
TRANSMISSION & RECEPTION TIMING CONTROL UNIT
120a
TRANSMISSION INITIATION
122
TRANSMISSION PULSE GENERATOR
TP
TD
RD
RPd
SW1
SW2
a
b
a
b
TD (TP2)
RP1
(UPSTREAM SIDE)
111d
(DOWNSTREAM SIDE)
PIPE
FLUID
111u
RD
RP2
TD (TP1)
102

FIG. 11

15/20

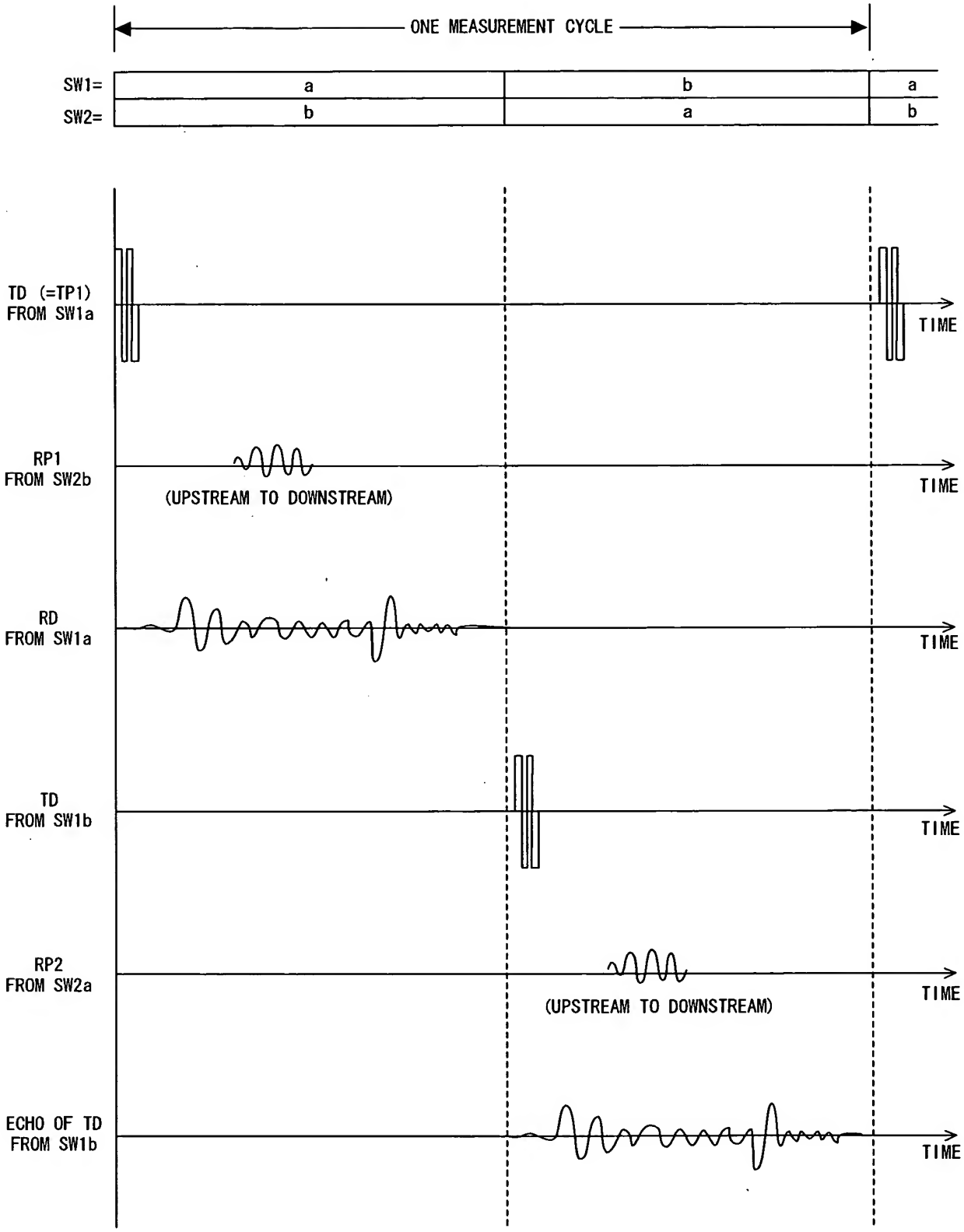

ONE MEASUREMENT CYCLE
SW1=
SW2=
a
b
a
b
a
b
TD (=TP1) FROM SW1a
TIME
RP1 FROM SW2b
(UPSTREAM TO DOWNSTREAM)
TIME
RD FROM SW1a
TIME
TD FROM SW1b
TIME
RP2 FROM SW2a
(UPSTREAM TO DOWNSTREAM)
TIME
ECHO OF TD FROM SW1b
TIME

FIG. 12

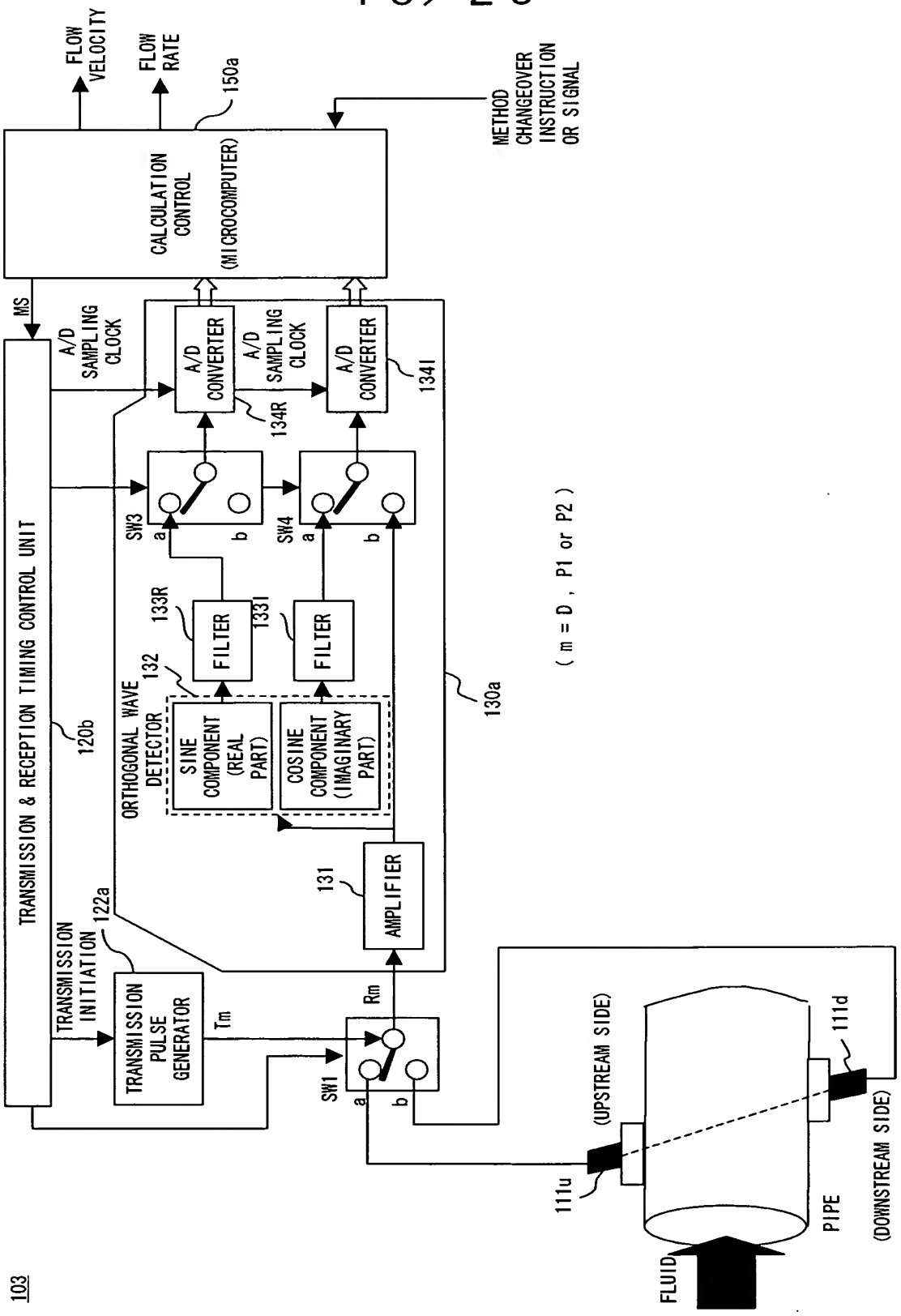

FLOW VELOCITY
FLOW RATE
150a
METHOD CHANGEOVER INSTRUCTION OR SIGNAL
CALCULATION CONTROL
(MICROCOMPUTER)
MS
A/D SAMPLING CLOCK
A/D CONVERTER
A/D SAMPLING CLOCK
A/D CONVERTER
134R
134I
SW3
SW4
a
b
133R
133I
FILTER
FILTER
ORTHOGONAL WAVE DETECTOR
132
SINE COMPONENT (REAL PART)
COSINE COMPONENT (IMAGINARY PART)
130a
120b
TRANSMISSION & RECEPTION TIMING CONTROL UNIT
131
AMPLIFIER
122a
TRANSMISSION INITIATION
TRANSMISSION PULSE GENERATOR
Tm
Rm
SW1
(UPSTREAM SIDE)
111d
111u
PIPE
(DOWNSTREAM SIDE)
FLUID
103
( m = D , P1 or P2 )

FIG. 13

STATES OF SW1 THROUGH SW4 IN MEASUREMENT OPERATIONS

| MEASUREMENT METHOD | SW3 AND SW4 | SW1 |
|---|---|---|
| PULSE DOPPLER METHOD | a | a |
| PROPAGATION TIME DIFFERENCE METHOD | b | SAME AS SW SHOWN BY FIG. 10 |

FIG. 14

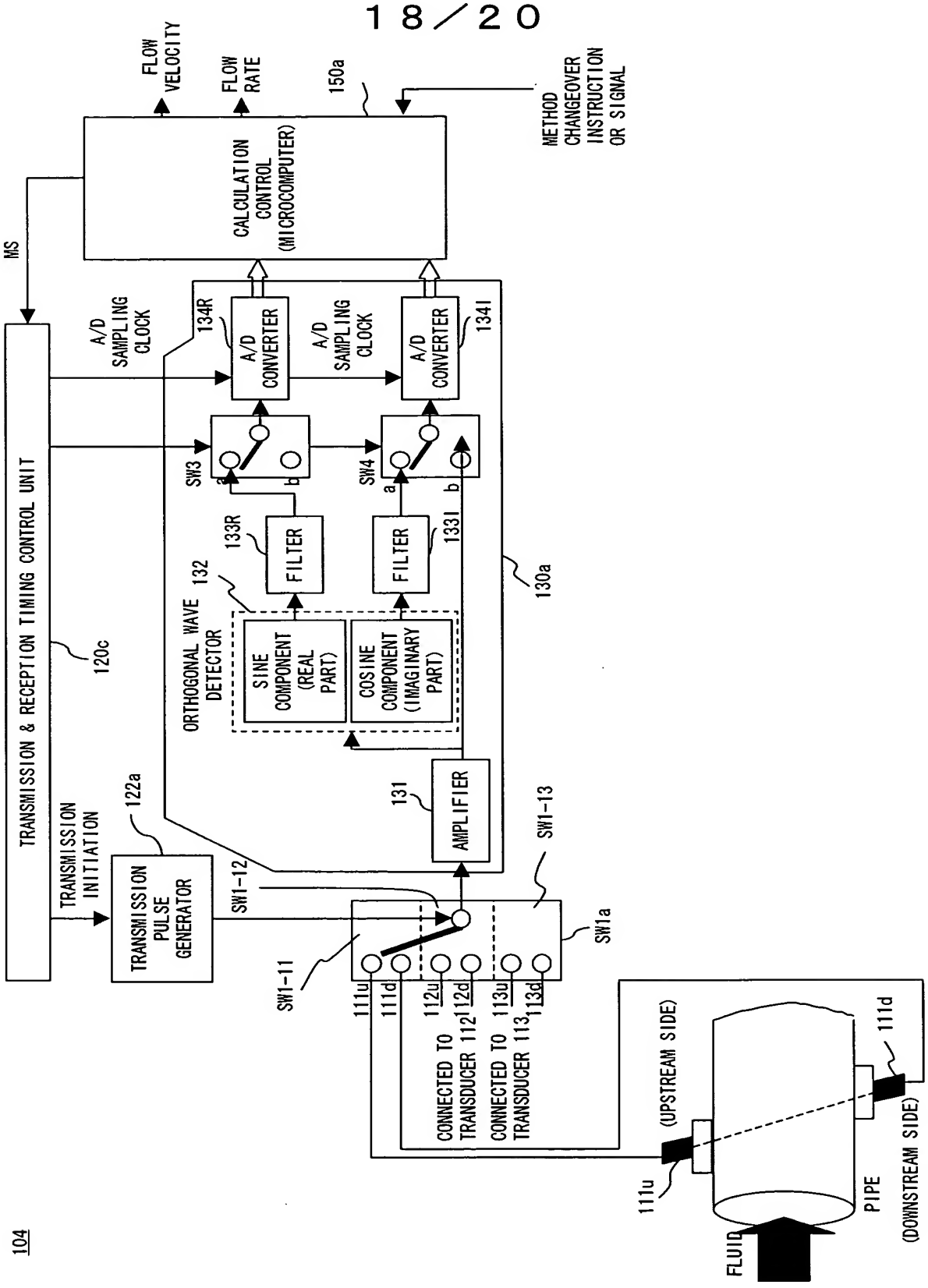

FLOW VELOCITY
FLOW RATE
150a
METHOD CHANGEOVER INSTRUCTION OR SIGNAL
CALCULATION CONTROL (MICROCOMPUTER)
MS
A/D SAMPLING CLOCK
134R
A/D CONVERTER
A/D SAMPLING CLOCK
134I
A/D CONVERTER
SW3
SW4
133R
FILTER
133I
FILTER
132
ORTHOGONAL WAVE DETECTOR
SINE COMPONENT (REAL PART)
COSINE COMPONENT (IMAGINARY PART)
130a
TRANSMISSION & RECEPTION TIMING CONTROL UNIT
120c
131
AMPLIFIER
122a
TRANSMISSION INITIATION
TRANSMISSION PULSE GENERATOR
SW1-12
SW1-13
SW1a
SW1-11
111u
111d
112u
112d
113u
113d
CONNECTED TO TRANSDUCER 112
CONNECTED TO TRANSDUCER 113
(UPSTREAM SIDE)
(DOWNSTREAM SIDE)
PIPE
FLUID
104

FIG. 15A

USING TWO PAIRS OF TRANSDUCERS

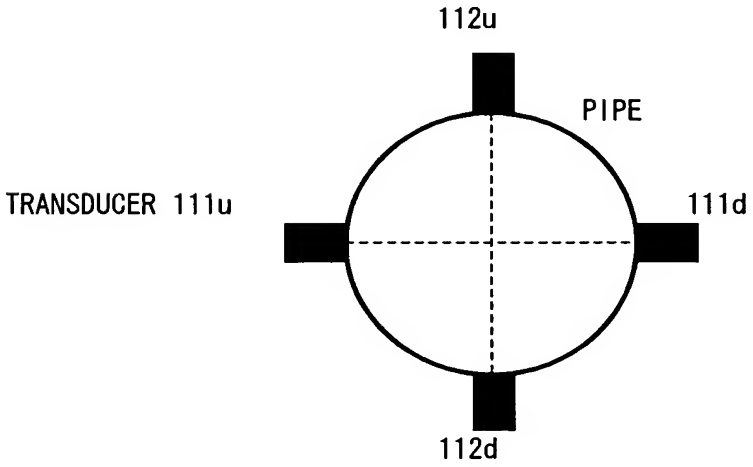



FIG. 15B

USING THREE PAIRS OF TRANSDUCERS

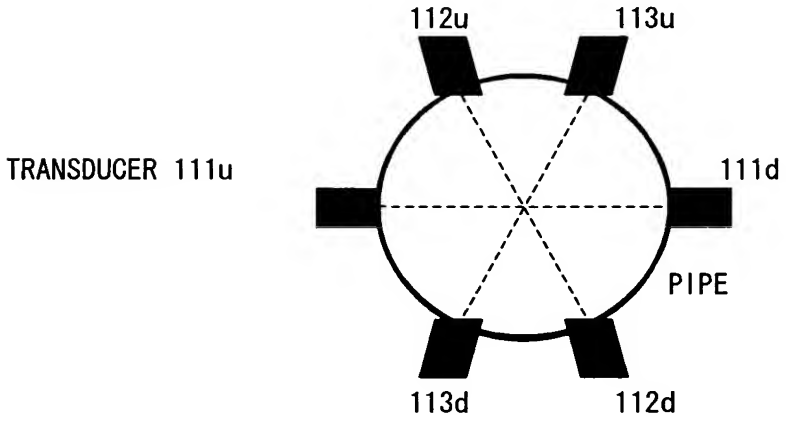



FIG. 15C

| MEASUREMENT METHOD | | SW3 AND SW4 | SW1-T (T=111, 112 or 113) |
|---|---|---|---|
| DOPPLER METHOD | | a | SW1-Tu |
| PROPAGATION TIME DIFFERENCE METHOD | TRANSDUCERS 111 112 113 | b | CONTROL SW1-T IN THE SAME WAY AS SW SHOWN BY FIG. 10 NB: THE u AND d CORRESPOND TO a AND b RESPECTIVELY AS SHOWN BY FIG. 10 |

FIG. 16